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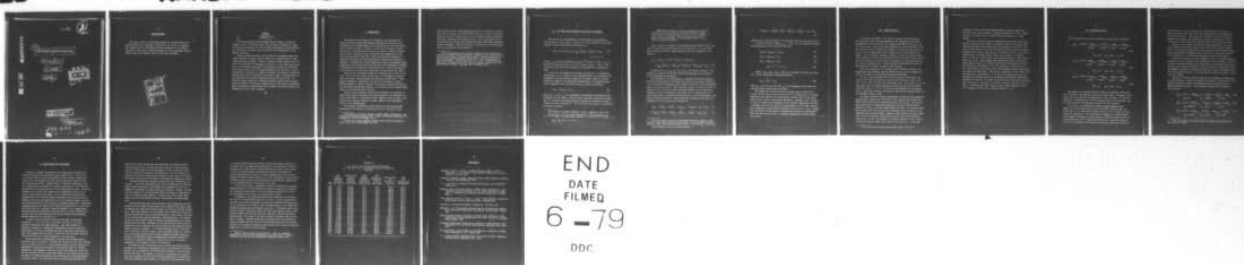
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DEFENSE BUDGET INTERACTIONS REVISITED

*(10)* by  
Robert Shishko

*(11)* June 1977

*(12)* 20p.

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ACKNOWLEDGMENTS

The author wishes to thank Dennis Aigner of The Rand Corporation and the University of Southern California for his efforts in adapting his original work on simultaneous equation estimation to the problem described in this paper, and Marian Shapley for her programming efforts, without which this research could not have been performed.

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SUMMARY

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The Despres-Dhrymes (D-D) model of defense budget interactions between the U.S., the Soviet Union, and the PRC is reexamined in light of the new CIA estimates of Soviet defense spending and the availability of a statistical technique that accounts for the simultaneity in the model's equations.

Using a common data base, the D-D model is reestimated using their single-equation technique, and the results are compared with the simultaneous equation technique. Neither technique yields estimates that can aid in the selection of strategies for the U.S. in the long-term competition. As currently, formulated, the adjustment process that underlies the D-D model may not be a very good description of the world. Certain assumptions of the model are indeed troublesome, and whatever interaction process exists may be concealed by the model's lack of discrimination in the composition of defense expenditures perceived by each side. It therefore seems worthwhile to explore interactive models that deal with specific arenas of the military competition and that allow for asymmetric lags and systematic misperceptions (for example, the elusive missile and bomber gaps) by one side or another.



## I. INTRODUCTION

The purpose of this paper is to reexamine work originally performed at Rand by Despres and Dhrymes<sup>1</sup> (hereafter called D-D) on the determinants of military budgets in the United States, the Soviet Union, and the People's Republic of China. In that work, D-D posit a model consisting of three equations in which each country's military expenditure in year  $t$  depends, in part, on the military expenditures of the other two countries in that year. Thus, each equation represents a reaction curve very much like those found in Cournot-type theories of oligopoly. Although such quantity-adjustment models are considered naive descriptions of the world, D-D were the first to my knowledge to estimate a *three-way* defense expenditure interaction model, thereby improving the state-of-the-art over the more conventional two-way interaction models.

There are two compelling reasons for reviewing the D-D work at this time. First, the CIA, within the last year, has published in unclassified form Soviet defense expenditure estimates for 1970-1975.<sup>2</sup> These figures represent a significant increase in CIA estimates of Soviet defense spending in rubles--doubling the previously classified estimates. The structural relationships estimated by D-D may be altered significantly simply by incorporating these new data.

Second, recent advances at Rand and the University of Wisconsin in simultaneous equation estimation have made available a new technique virtually tailor-made to the problem at hand, whereas in the D-D paper, each equation was estimated separately without regard to the simultaneous nature of the proposed model.

The original classified data base used by D-D was discarded upon publication of the results, so there was no way to reconstruct their

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<sup>1</sup> John Despres and Phoebus Dhrymes, *Defense Budget Interactions: Preliminary Econometric Analysis of U.S., Soviet, and Chinese Competition (U)*, Confidential, R-1390-PR, November 1973.

<sup>2</sup> Central Intelligence Agency, *Estimated Soviet Defense Spending in Rubles, 1970-1975*, SR 76-10121U, May 1976.

observations exactly. Fortunately, much of the data needed are available with some effort from unclassified sources, an effort considerably lessened by the CIA's publication of Soviet defense spending estimates. Therefore, working with unclassified data, I have reestimated the D-D model using their statistical technique and then using the simultaneous equation technique. This will allow us to compare the results side-by-side on the same set of observations.<sup>1</sup>

<sup>1</sup>Correct estimates of the reaction coefficients are important on theoretical grounds because the dynamic stability of all action-reaction type arms race models, including the D-D model, depends crucially on certain relationships among the coefficients. For an appreciation of this, see Michael D. Intriligator and D. L. Brito, "Formal Models of Arms Races," presentation to the 13th North American Conference of the Peace Research Society, Cambridge, Mass., November 1975.

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<sup>1</sup>John Beesree and Thomas Dwyer, "Soviet Budget Interactions: Preliminary Econometric Analysis of U.S., Soviet, and Chinese Competition (U)", Confidential, R-1390-45, November 1971.

<sup>2</sup>Central Intelligence Agency, Estimated Soviet Defense Spending in Millions, 1970-1975, SR 76-10114, May 1976.



## II. THE MODEL AND ALTERNATIVE STATISTICAL TECHNIQUES

The structural relationships of the D-D model are described and rationalized in their report.<sup>1</sup> Each of the three equations in the model assumes a linear form which can be written as

$$y_{i,t} = \beta_{0i} + \lambda_i y_{i,t-1} + \sum_{j \neq i} \beta_{ji} y_{j,t} + \beta_{xi} x_{i,t} + u_{i,t} \quad (1)$$

$$i, j = 1, 2, 3$$

where  $y_{i,t}$  is defense expenditures in the  $i^{\text{th}}$  country in year  $t$ ,  $x_{i,t}$  is the GNP (or GNP equivalent) of the  $i^{\text{th}}$  country in year  $t$ , and  $u_{i,t}$  is a structural error term that may exhibit an autoregressive pattern over time.

In Eq. (1), the expenditure variables are assumed to be determined endogeneously by the system of three equations, while GNP is assumed to be determined by forces entirely outside of the system--that is, the GNP variable is assumed to be determined exogeneously. D-D assumed without loss of generality that the error terms  $u_{i,t}$  could be written as

$$u_{i,t} = \rho_i u_{i,t-1} + \epsilon_{i,t} \quad (2)$$

where  $|\rho_i| < 1$  and  $\epsilon_{i,t}$  were independent and normally distributed random variables with zero means. That the error terms were autoregressive meant that the standard simultaneous equation estimation techniques no longer yielded consistent estimators.<sup>2</sup> D-D justified their choice of statistical techniques by saying:

<sup>1</sup> John Despres and Phoebus Dhrymes, *op cit.*, Appendix A, pp. 21-24.

<sup>2</sup> An estimate  $\hat{\beta}$  of  $\beta$  is called consistent if the probability limit of  $\hat{\beta}$  as the sample size approaches infinity is  $\beta$ , that is, if for all  $\epsilon > 0$

$$\lim_{n \rightarrow \infty} \text{Prob} (|\hat{\beta} - \beta| < \epsilon) = 1.$$



"Faced with the choice of using a simultaneous equations procedure (such as two-stage least squares) without taking into account the autoregressive character of the residuals, or single equation procedures (such as ordinary regression), which do take into account the autoregressive nature of the errors, we chose the latter."

Their procedure, standard in the econometrician's bag of tricks, was to work with each equation separately and search over  $\rho_1$  for the value that minimizes the sum of squared errors in the OLS regression of the equation:

$$y_{1,t} - \rho_1 y_{1,t-1} = \alpha_{01} + \lambda_1 (y_{1,t-1} - \rho_1 y_{1,t-2}) + \sum_{j \neq 1} \beta_{j1} (y_{j,t} - \rho_1 y_{j,t-1}) + \beta_{11} (x_{1,t} - \rho_1 x_{1,t-1}) + \epsilon_{1,t} \quad (3)$$

Estimates for  $\rho_1$ ,  $\beta_{01}$ ,  $\beta_{j1}$ ,  $\beta_{11}$ , and  $\lambda_1$  are thereby obtained.<sup>1</sup> The quantity  $\rho_1$  reported at the end of each such regression is an estimate of the autoregressive parameter.

As mentioned in the introduction, a technique has been developed at Rand and the University of Wisconsin that permits simultaneous estimation of the structural coefficients while taking into account the autoregressive nature of the error terms.<sup>2</sup> This technique, however, goes beyond that envisioned by D-D in that the Rand technique produces a set of consistent estimates even for situations in which some of the variables may be observed with error, a complication not permitted in the D-D technique. Letting an asterisk indicate a variable that may be observed with error, the equations of the D-D model can be written as:

$$y_{US,t} - \beta_{12} y_{C,t}^* - \beta_{13} y_{R,t}^* - \lambda_1 y_{US,t-1} - \beta_{11} x_{US,t} - \beta_{01} = u_{US,t} \quad (4)$$

$$-\beta_{21} y_{US,t} + y_{C,t}^* - \beta_{23} y_{R,t}^* - \lambda_2 y_{C,t-1} - \beta_{22} x_{C,t} - \beta_{02} = u_{C,t} \quad (5)$$

<sup>1</sup> See any standard reference on econometrics such as Johnston, *Econometrics Methods*, McGraw Hill, New York, 1963, for the algebraic manipulation that makes this regression equation work. Note that  $\alpha_{01} = \beta_{01} (1 - \rho_1)$ .

<sup>2</sup> This technique has not yet been published.

$$-\beta_{31}y_{US,t} - \beta_{32}y_{C,t}^* + y_{R,t}^* - \lambda_3 y_{R,t-1}^* - \beta_{33}x_{R,t}^* - \beta_{03} = u_{R,t} \quad (6)$$

using US for the United States, C for the PRC, and R for the Soviet Union.

As before, the error terms  $u_{i,t}$ ,  $i = US, C, R$ , are assumed to exhibit an autoregressive error pattern of the form:

$$u_{US,t} = \rho_1 u_{US,t-1} + \epsilon_{US,t} \quad (7)$$

$$u_{C,t} = \rho_2 u_{C,t-1} + \epsilon_{C,t} \quad (8)$$

$$u_{R,t} = \rho_3 u_{R,t-1} + \epsilon_{R,t} \quad (9)$$

$$|\rho_i| < 1 \quad i = 1, 2, 3 \quad (10)$$

Further,  $y_{C,t}^*$ ,  $y_{R,t}^*$ ,  $x_{C,t}^*$ , and  $x_{R,t}^*$  are assumed to differ from their true values according to the general pattern

$$y_{C,t} = y_{C,t}^* + \delta_{C,t} \quad (11)$$

where  $y_{C,t}$  is the true value and  $\delta_{C,t}$  is an independent and normal distributed random variable with mean zero.

The assumption of observation error applies only to Soviet and Chinese defense expenditures and GNP--that is, I assume that U.S. defense expenditures and GNP are true observations, whereas those of the Soviet Union and PRC contain random error components. Although I have no reason to rule out random error components in U.S. defense expenditures and GNP, I strongly feel that the errors in the measurement of the other variables are considerably larger and more prevalent than in the U.S. data. Furthermore, estimation of the model is considerably enhanced by the assumption that the measured values for U.S. defense expenditures and GNP reflect true values.



### III. SOURCES OF DATA

To estimate the model of the previous section, unclassified data were obtained on real defense expenditures (or estimated real defense expenditures), and on real GNP (or estimated real GNP) for the U.S. and the Soviet Union. Each series (see Appendix A) is stated in terms of its own national currency (dollars and rubles) as relevant exchange rates can only be crudely approximated and are likely to be totally meaningless anyway. For the People's Republic of China, an *index* of national industrial production in 1957 yuan (1965=100.0) is used in lieu of GNP because it is more indicative of the resources available for military production and strategic modernization. Chinese defense expenditures are measured in constant 1970 dollars instead of local currency.

Data were obtained for the calendar years 1950-1975 inclusive, but because the Rand technique requires observations on the data lagged four years,<sup>1</sup> the model is estimated for the period 1954-1975.

The U.S. defense expenditures series in constant 1970 dollars came from the *Stockholm International Peace Research Institute (SIPRI) Yearbook*, (1972, 1975), The MIT Press, Cambridge, Mass. An estimate of the calendar year 1975 U.S. defense expenditures came from the *Annual Defense Department Report FY 1976 and FY 1977*, and was adjusted to 1970 dollars. The U.S. GNP series constant 1972 dollars came from the *Economic Report of the President* (January 1976).

The series on Soviet defense expenditures in constant 1970 prices was constructed by linking the SIPRI (1972, 1975) constant price index from 1950 to 1970 with CIA ruble expenditures from 1970 to 1975. The CIA numbers came from the unclassified publication, *Estimated Soviet Defense Spending in Rubles, 1970-1975*, SR76-10121U, May 1976. The series on Soviet GNP in 1970 rubles was constructed by extending CIA data found in an unpublished table entitled "USSR: Indexes of GNP by Sector of Origin, 1950-1972" to 1975 by applying estimated real growth rates of GNP from the publication, *Research Aid Handbook of Economic Statistics, 1975*, Central Intelligence Agency, A(ER) 75-65, August 1975, Table 15. A ruble GNP

<sup>1</sup>The D-D technique requires observations lagged two years.



estimate was made by dividing estimated Soviet military expenditures in 1975 by the estimated share of military expenditures in GNP. Using the link, the index series for Soviet GNP was converted to a ruble series.

The series on Chinese defense expenditures was constructed by combining information from a variety of sources. Data for the years 1950-1959 was obtained from *Ten Great Years, Statistics on the Economic and Cultural Achievements of the PRC*, PRC State Statistical Bureau, Foreign Language Press, Peking, 1960, page 23. For 1959 and 1960, I used *Current Background*, No. 615 (April 1960), "Text of Vice Premier L. Fu-chun's Report on the Draft 1960 Economic Plan," Peking, March 30, 1960 (on microfilm), pp. 26-38. These numbers were indexed and linked to the dollar figures given in the *SIPRI Yearbook* (1975) for 1957 through 1973, which are in constant 1970 dollars. The 1974 estimate was obtained from Lt. Col. Norman Smith of the Arms Control and Disarmament Agency (ACDA) based on studies performed there. This figure, originally in 1973 dollars, was then deflated to 1970 dollars. K. C. Yeh of The Rand Corporation then provided an estimated growth rate for Chinese real defense expenditures between 1974 and 1975. The index series for Chinese industrial production came from Arthur G. Ashbrook, Jr., "China: Economic Overview, 1975" in *China: A Reassessment of the Economy*, Joint Economic Committee of the U.S. Congress, July 10, 1975, especially Table 2, p. 23.

#### IV. ESTIMATION RESULTS

The D-D estimation technique yielded the following three equations:

$$y_{US,t} = -20.31 + .798y_{US,t-1} - 2.79y_{C,t} - .599y_{R,t} + .085x_{US,t} \\ (.578)^{\dagger} \quad (-2.29)^{\dagger} \quad (-1.33) \quad (3.54)^{\dagger} \quad (12)$$

$$R^2 = .83 \quad SE = 4.06 \quad \hat{\rho} = .12$$

$$y_{C,t} = -1.744 + .634y_{C,t-1} + .006y_{US,t} + .123y_{R,t} + .002x_{C,t} \\ (3.95)^{\dagger} \quad (0.31) \quad (2.76)^{\dagger} \quad (0.30) \quad (13)$$

$$R^2 = .97 \quad SE = 0.56 \quad \hat{\rho} = .16$$

$$y_{R,t} = -3.975 + .677y_{R,t-1} + .073y_{US,t} - .383y_{C,t} + .048x_{R,t} \\ (2.79)^{\dagger} \quad (1.34) \quad (-0.54) \quad (2.59)^{\dagger} \quad (14)$$

$$R^2 = .97 \quad SE = 1.89 \quad \hat{\rho} = 0$$

The figures in parentheses directly under the estimated coefficients are t-statistics that indicate statistical significance. The dagger indicates that the coefficient is significant at the .05 level.  $R^2$  is the coefficient of determination, SE is the standard error of the estimate, and  $\hat{\rho}$  is the estimated autoregressive parameter for each equation.

In Eq. (12), the coefficient on Soviet defense spending would appear to have the wrong sign, but the t-statistic indicates that the coefficient is not statistically different from zero or a small positive number for that matter. The coefficient on lagged U.S. defense expenditures suggests bureaucratic inertia plays a relatively important part in the determination of U.S. defense expenditures--at least when compared with the corresponding coefficients in the Chinese and Soviet equations.



The coefficient on GNP in equation (12) indicates that an increase in GNP by one 1970 dollar would lead to an increase in defense expenditures by .093 1970 dollars.<sup>1</sup> The significant coefficient on Chinese defense expenditures suggests the substitution of Chinese expenditures for U.S. expenditures in maintaining the military balance with the Soviet Union.

Equation (13) suggests that Chinese defense expenditures are determined primarily by previous Chinese and current Soviet defense expenditures. U.S. defense expenditures do not apparently influence the Chinese, which seems somewhat paradoxical given that the U.S. has fought two wars on the periphery of the PRC during the period covered by the sample.

The Soviet equation, Eq. (14), suggests that U.S. and Chinese defense expenditures do not predict Soviet expenditures very accurately. The previous year's defense expenditure and Soviet GNP are the primary determinants of this year's defense expenditure. The coefficient on Soviet GNP, which is the marginal propensity to spend on defense out of GNP, is curiously lower than the average propensity to spend on defense, which runs between .11 and .15 in the sample.

Although the results obtained using the D-D estimation technique were not unsatisfactory, a number of anomalies are evident. Unfortunately, the estimates obtained using the simultaneous equation technique are not wholly satisfactory either. The following equations were obtained by that technique:

$$y_{US,t} = 174.9 - .036y_{US,t-1} - 15.2y_{C,t}^* + 3.19y_{R,t}^* + .13x_{US,t} \quad (15)$$

$$\hat{\sigma}_{\delta\delta} = 0 \quad \hat{\sigma}_{\epsilon\epsilon} = 2506.6 \quad \hat{\rho} = 1.15$$

$$y_{C,t}^* = 7.375 + .260y_{C,t-1}^* - .170y_{US,t} + .201y_{R,t}^* + .015x_{C,t}^* \quad (16)$$

$$\hat{\sigma}_{\delta\delta} = 4029.5 \quad \hat{\sigma}_{\epsilon\epsilon} = 26.1 \quad \hat{\rho} = .85$$

$$y_{R,t}^* = 83.85 - 1.34y_{R,t-1}^* - 30.3y_{C,t}^* - .94y_{US,t} + 1.35x_{R,t}^* \quad (17)$$

$$\hat{\sigma}_{\delta\delta} = 1151.2 \quad \hat{\sigma}_{\epsilon\epsilon} = 12.8 \quad \hat{\rho} = 1.08$$

<sup>1</sup>This is obtained by dividing .085 by the implicit GNP deflator for 1970 relative to 1972.



The term  $\hat{\sigma}_{\delta\delta}$  is an estimate of the standard error of  $\delta_{1,t}$  in Eq. (11), and  $\hat{\sigma}_{\epsilon\epsilon}$  is an estimate of the standard error of  $\epsilon_{1,t}$  in Eqs. (7) through (9). Unfortunately, it is not possible at this time to calculate a number corresponding to the t-statistic; as a result, the statistical significance of each coefficient is unknown.

Some general observations can be made. First, U.S. defense expenditures seem to be more reactive to Soviet and Chinese expenditures, increasing with increasing Soviet expenditures and decreasing with increasing Chinese expenditures. The marginal propensity to spend on defense out of GNP is also higher than previously estimated, while the influence of past years' expenditures is lower than previously estimated.

Second, the Chinese seem to be more responsive to both Soviet and U.S. defense expenditures than previously estimated with higher Soviet expenditures or lower U.S. expenditures implying higher Chinese expenditures.

Third, the coefficients on the Soviet equation are so extraordinary as to make one wonder whether the Soviets are playing the same game. An alternative explanation is that the coefficients in Eq. (17) have standard errors large enough to support more reasonable coefficients.<sup>1</sup>

Some explanations of these statistical results are discussed in the next section, but it is worthwhile to mention here the possibility that the three-way simultaneous adjustment process that underlies the model may just not be a very good description of the world. It is difficult to reconcile in such a model rapidly declining U.S. defense expenditures since 1968 with rapidly rising Soviet expenditures, even with the strategic realignment of the Chinese in that period. Our understanding of the gross interaction process is probably worse than we credit ourselves with, in that naive models which have achieved a certain amount of political respectability explain very poorly the past course of the military competition.

<sup>1</sup>In the Chinese equation, the estimate of  $\rho$  is less than one as required by the model. In the U.S. and Soviet equations, the corresponding estimates of  $\rho$  are greater than one, though not so much as to rule out the possibility of the true value being less than one.

The estimated coefficients of the D-D model (and other Cournot-type models) are the result of both the objectives or goals of each side and their relative efficiencies. There is a kind of "uncertainty principle" involved here. The coefficients do not enable us to distinguish, for example, the situation in which the Soviets are seeking strategic superiority while the U.S. is seeking only deterrence, and both are equally efficient, from the situation in which the Soviets are also seeking only deterrence, but are less efficient at converting resources into strategic systems.<sup>1</sup> If we precisely knew both sides' "objective functions," we could probably say a great deal about who has the competitive advantage.<sup>2</sup> Similarly, knowledge of the relative efficiency would presumably lead to some revelations about goals and objectives.

An opponent's *current and projected forces and their deployment* may be used by each side as the measure of the threat against which military forces must be sized and shaped. For each force level and force deployment, there is a required expenditure of resources, but each expenditure level may imply vastly different combinations of force size and force deployment; at the same cost, smaller forces in a forward deployment may appear more threatening than larger forces stationed at a distance. Military expenditures alone may hide too much to be the principal variable in a model of military competition.

<sup>1</sup> Consider the simple case of two quantity-adjusting firms competing in a market. One firm seeks to maximize profits while the other seeks to maximize market share subject to achieving a fixed profit; both firms produce at the same constant marginal cost. The Cournot equilibrium that results can be identically reproduced by having both firms maximize profits and one firm with a marginal cost that is some multiple of the others.

<sup>2</sup> The concept of competitive advantage has been discussed in unpublished papers by this author.



## V. DEFICIENCIES AND CONCLUSIONS

There are a number of problems in the formulation and estimation of the type of quantity adjustment model posited by D-D. First, it is clear that *perceived*, and not necessarily actual, defense expenditures of the other two competing countries should enter each country's equation (reaction function). Whether Soviet or Chinese perceptions of the U.S. defense effort is aided by the largely open nature of the appropriation process in the United States, will perhaps never be known. We have no reliable way to predict how changes in U.S. expenditures will be perceived by the Soviets and Chinese. It is likely that particular suborganizations of the Soviet military bureaucracy will focus on specific changes in the size and composition of the U.S. military budget, and that each suborganization will be sensitive to changes affecting it. Among these suborganizations then, there may be different perceptions as to the necessity (and size) of a response to specific changes in U.S. expenditures. How these different perceptions are coalesced or at least reconciled requires a detailed understanding of the Soviet military decisionmaking process that we do not currently have.

A second related observation concerns the lags in developing perceptions. In the D-D model, adjustments are made by all three countries immediately and simultaneously. Less than immediate responses to changes in a competitor's expenditures seem more realistic, particularly in view of the additional lag in converting "expressions of will" into useable military forces. To be fair, the D-D model should be tested using different, perhaps asymmetric, lag structures.

Third, there are strong reasons to believe that the structural coefficients might be different if Korean and Vietnam war costs were excluded from the observations on U.S. (and possibly Chinese) defense expenditures. Experimental regressions performed by D-D indicated that U.S. defense expenditures were augmented beyond the cost of the Korean war itself during the rearmament period of the early 1950s, but the Vietnam war did not increase U.S. defense expenditures over and above the costs attributable to the war itself. For the Soviet Union, no effect was detectable for



either war, and for the Chinese only the Korean war seemed to affect military expenditures. Because the sample from which the regression results in this paper were obtained began in 1954, no special attribution (or deletion) was made for the Korean war. The U.S. equation is based on an expenditure series that contains all war costs; the Chinese and Soviet equations are also based on that same U.S. expenditure series.

A fourth observation concerns the inaccuracy and insufficiency of the data. The Soviet and Chinese data used in estimating the model most likely contain systematic (non-random) error components which are not explicitly considered in either estimation technique. Further, the consistency property of the simultaneous equation estimates is guaranteed only for infinitely large samples. A sample size two to three times larger than that used would be needed to approximate the large sample case.

Having identified some of the problems in the formulation and estimation of the D-D model in particular, let me address some larger issues of modeling the interaction process within the long term military competition. That there appears to be no reliable way to model the interaction process does not mean that no interaction exists. More likely, the interaction process takes place through more subtle mechanisms. For example, in the U.S. each service seeks to justify existing programs and to gain resources for new ones. Similarly, in the Soviet Union, each service or branch has its own concerns, only some of which can be addressed with the limited resources available. If no organizational entity is concerned with a particular military problem, then programmed changes by a competitor in that arena may very easily "slip through the cracks" and go unnoticed. Alternatively, when an organization's principal mission is threatened, programmed changes by a competitor in that arena may be exaggerated in an attempt to secure new resources.

To understand the interaction process, we must know how and where estimates of a competitor's expenditures enter the bureaucratic planning process, who is responsible for producing the estimates, who uses them, and who sees them. For example, in the U.S., the Secretary of Defense may use an estimate of total Soviet defense expenditures in arguing his case with Congress, public opinion, or within the Administration, while

at the same time drawing upon specific Soviet procurement estimates in testimony before a Congressional committee on the procurement line item. Working level staffs may use current and projected Soviet force levels to size and shape possible counterefforts and may use estimates of Soviet expenditures by mission to justify programs only after the submission of initial budget requests, if at all; estimates of Soviet defense expenditures may be sliced and recombined in different ways depending on the way suborganizations of DoD want to use them.

In the Soviet Union, the Red Army's man in the Politburo may use programmed changes in U.S. expenditures of forces to argue for an increase in a particular Army project. He is not likely to argue for a cut in Army programs, even in face of a cut in the U.S. Army.<sup>1</sup>

To summarize, the adjustment process that underlies the D-D model may not be a very good description of the world. Certain assumptions of the model are indeed troublesome, and whatever interaction process exists may be concealed by the model's lack of discrimination in the composition of defense expenditures perceived by each side. *It therefore seems worthwhile to explore interactive models that deal with specific arenas of the military competition and that allow for asymmetric lags and systematic misperceptions (for example, the elusive missile and bomber gaps) by one side or another.* Because alternative hypotheses about how estimates of opponent expenditures are used internally may generate different specifications of the interaction process, exploration of the "reaction functions" should not be confined to the D-D model.

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<sup>1</sup>This is the so-called "ratchet-effect." See A. W. Marshall, "Bureaucratic Behavior and the Strategic Arms Competition," Southern California Arms Control and Foreign Policy Seminar, October 1971.



## Appendix A

**U.S., SOVIET, AND CHINESE DEFENSE EXPENDITURES,  
U.S. AND SOVIET GNP, AND CHINESE INDUSTRIAL PRODUCTION,  
1950-1975**

Year	PRC Defense Spending (Billions of 1970 \$)	United States Defense Spending (Billions of 1970 \$)	USSR Defense Spending (Billions of 1970 Rubles)	PRC Industrial Production (Index 1965 = 100)	United States GNP (Billions of 1972 \$)	USSR GNP (Billions of 1970 Rubles)
1950	2.055	30.315	18.4	13.5	533.5	113.2
1951	3.672	49.552	21.4	19.0	576.5	120.3
1952	3.172	70.100	24.2	24.0	598.5	129.7
1953	4.124	71.978	24.5	30.5	621.8	139.6
1954	4.220	62.370	22.2	35.0	613.7	149.8
1955	4.720	58.850	24.9	36.5	654.8	163.9
1956	4.444	59.645	22.6	44.0	668.8	175.3
1957	4.000	60.825	22.4	50.0	680.9	184.4
1958	3.700	60.858	21.8	72.5	679.5	200.5
1959	4.100	61.192	23.6	88.5	720.4	212.3
1960	4.100	59.554	23.4	92.0	736.8	224.1
1961	4.800	62.008	29.1	54.0	755.3	238.6
1962	5.600	67.241	31.9	57.0	799.1	250.8
1963	6.300	66.280	35.0	68.5	830.7	254.4
1964	7.500	64.096	33.4	81.5	874.4	275.6
1965	7.900	63.748	32.1	100.0	925.9	292.9
1966	8.900	76.043	33.6	115.5	981.0	313.3
1967	8.600	87.730	36.3	101.0	1,007.7	331.0
1968	8.900	90.103	41.9	111.0	1,051.8	351.5
1969	11.100	86.274	44.4	132.5	1,078.8	363.6
1970	12.000	77.854	45.0	156.5	1,075.3	393.1
1971	13.400	71.776	46.0	170.5	1,107.5	411.2
1972	13.400	72.087	47.1	185.5	1,171.1	421.8
1973	13.100	68.586	50.4	208.0	1,233.4	452.1
1974	13.500	66.351	52.8	216.0	1,210.7	469.0
1975	13.900	64.320	56.0	242.0	1,186.4	479.8

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